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Photogrammetric Assessment of Flexural Induced Cracking in Reinforced Concrete Beams under Service Loads

Brad Pease, Mette Geiker,
Henrik Stang, and Jason Weiss

2ND International RILEM Symposium,
September 11-13, 2006

Outline of Today's Talk

- Motivation & Goal
- Experimental Investigation
 - Sample Geometry
 - Three-Dimensional Photogrammetry Technique
- Test Results
 - Crack Geometry
 - Crack Measurements
- Conclusions

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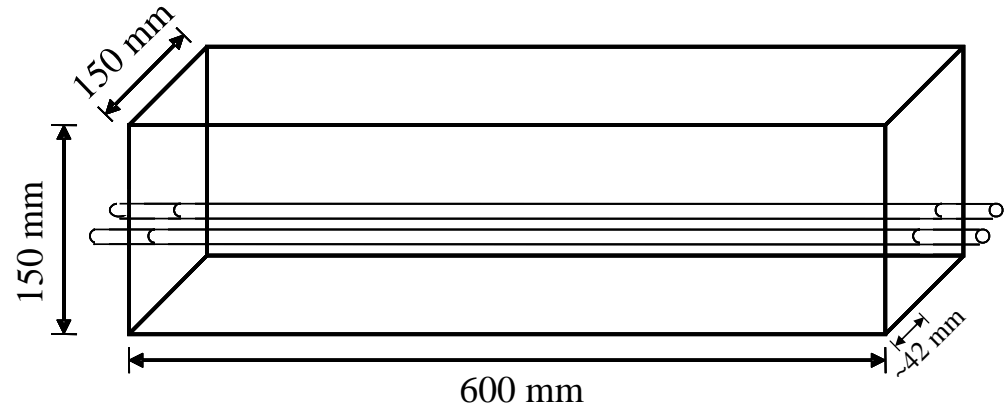
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Motivation and Goal

- Motivation
 - Cracking in concrete affects ingress and corrosion (i.e. service life)
 - Cracking in reinforced concrete is complicated by slip and separation at reinforcing bar
- Goal
 - Quantify crack geometry in reinforced concrete beam during loading

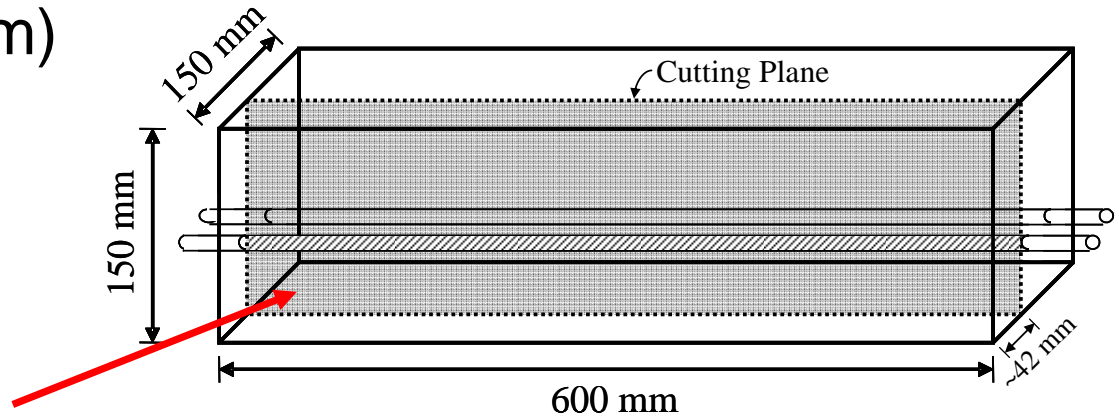
Experimental Observation of Cracks: Sample Geometry and Loading

- Reinforced beams
(150 x 150 x 600 mm)



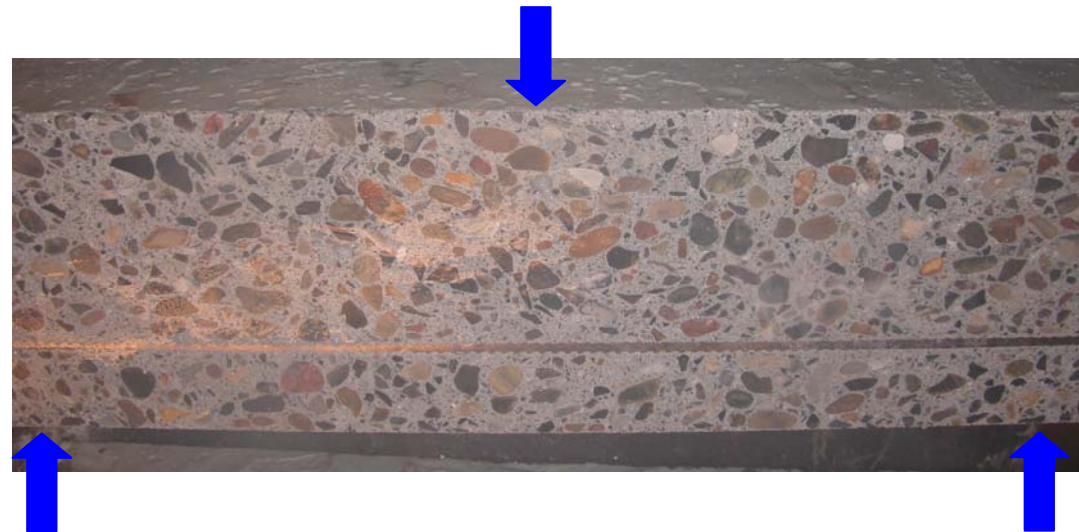
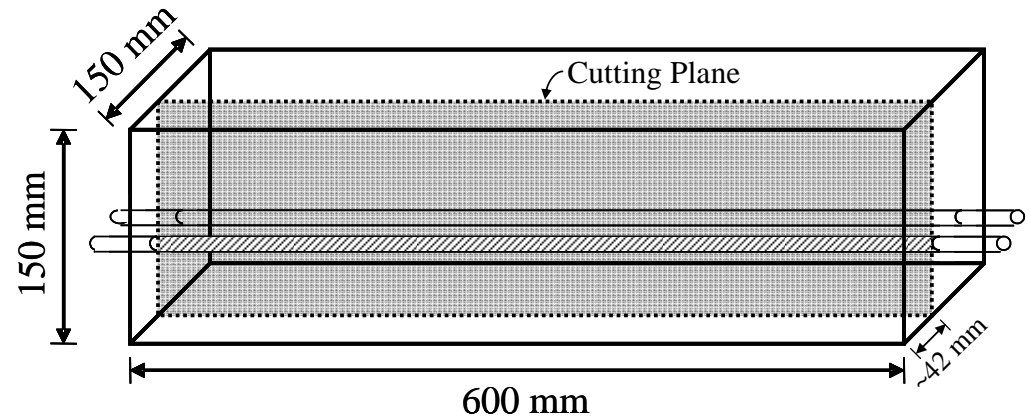
Experimental Observation of Cracks: Sample Geometry and Loading

- Reinforced beams (150 x 150 x 600 mm)
- Face of concrete removed
- Exposed reinforcement and aggregate



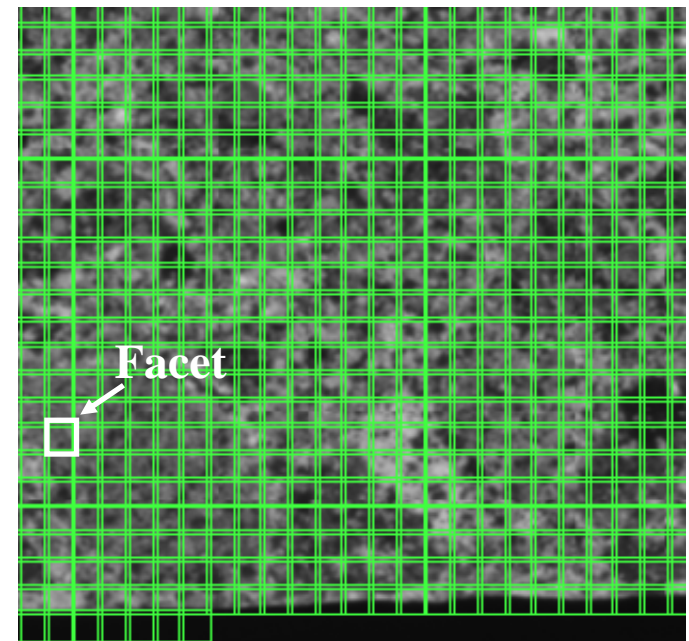
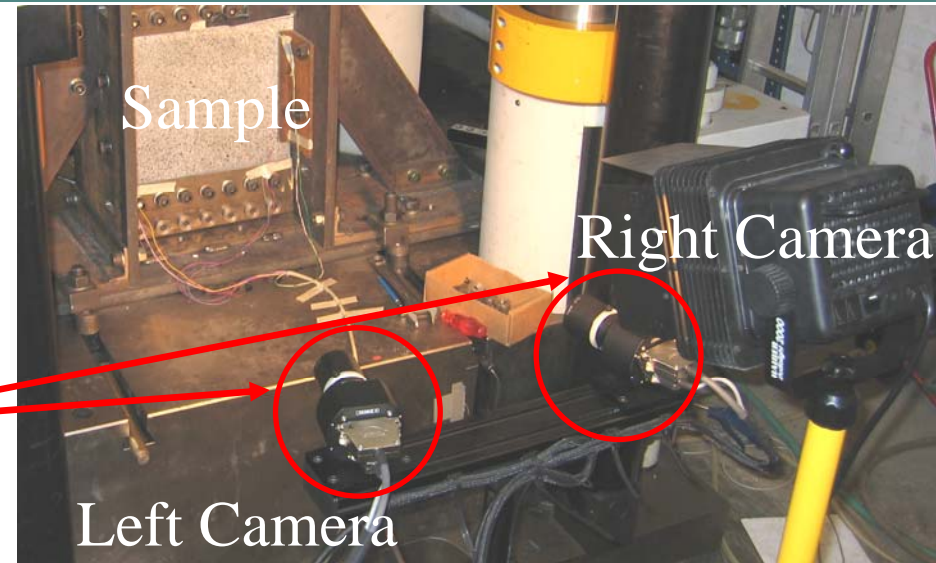
Experimental Observation of Cracks: Sample Geometry and Loading

- Reinforced beams
(150 x 150 x 600 mm)
- Face of concrete removed
- Exposed reinforcement and aggregate
- 3-Point bending
 - 1.0 and 1.8 times estimated cracking load (13 and 25.2 kN)
 - 35 kN



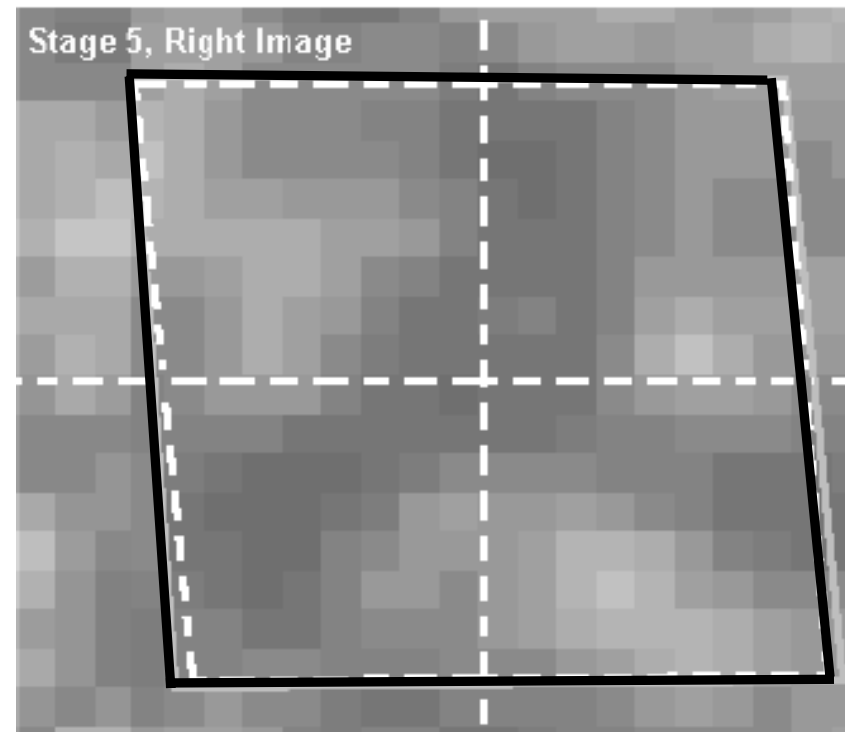
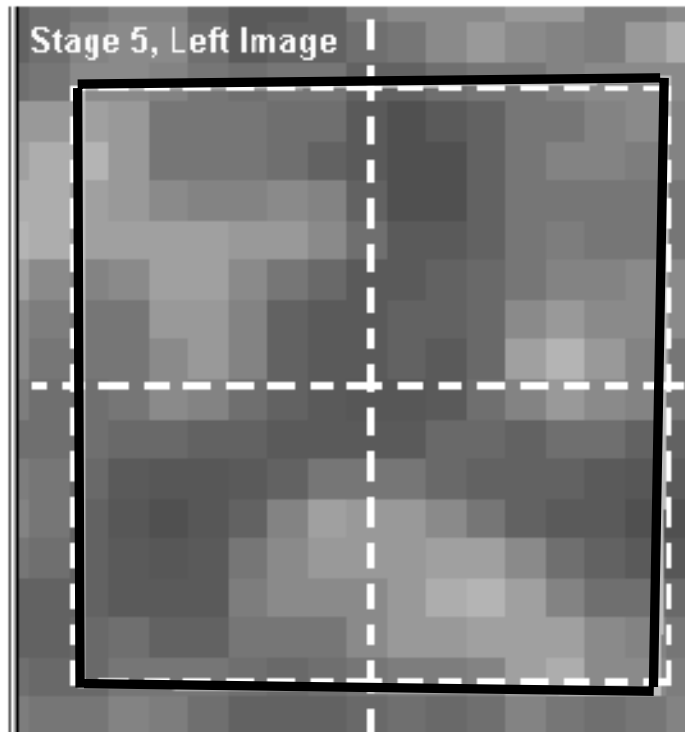
3-D Photogrammetry

- Photogrammetry quantifies cracking during loading
- Two digital cameras placed equidistant from sample, focused on same point collect images
- Images separated into a mesh by software
 - Individual mesh box = facet



3-D Photogrammetry: General Measurement Process

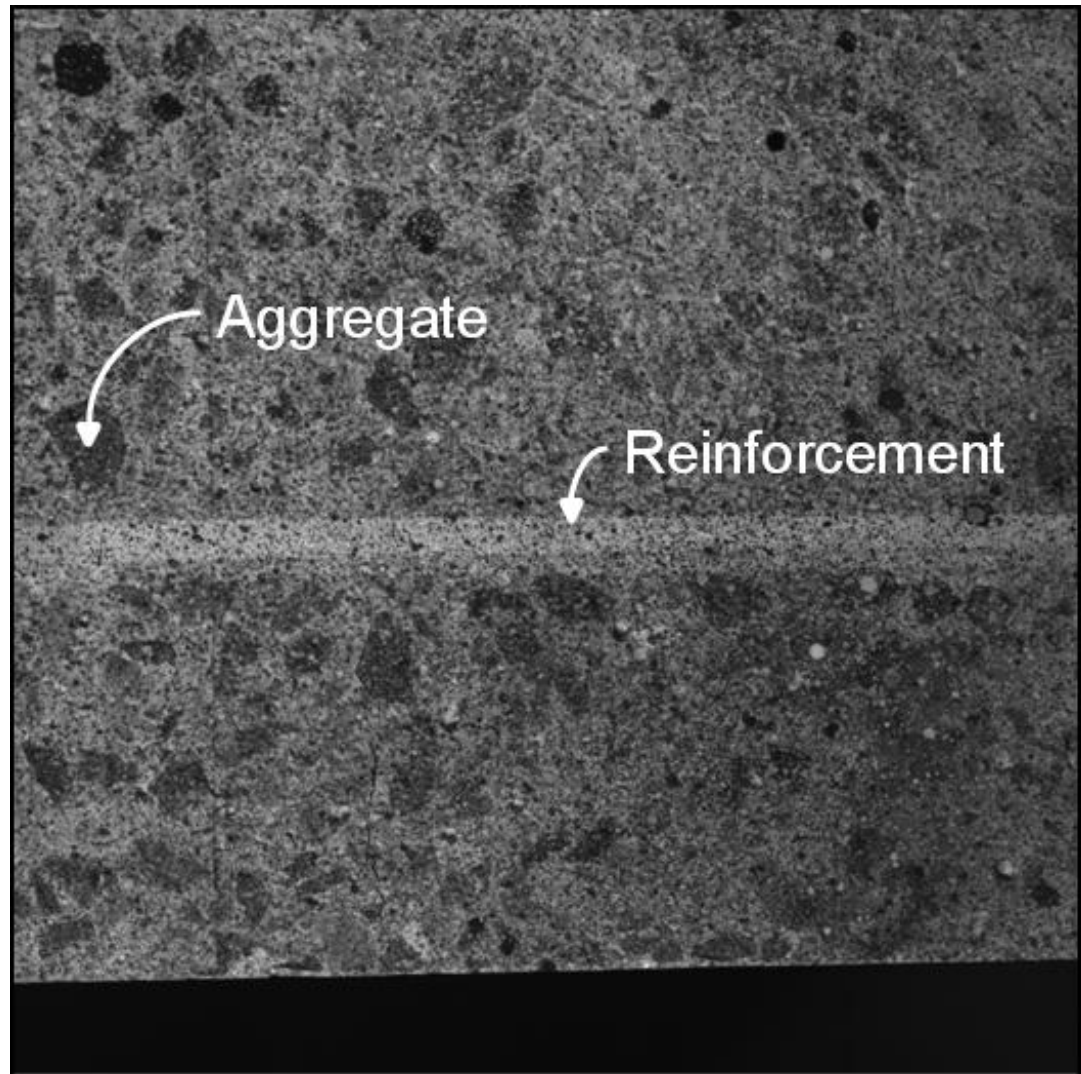
- Coordinates assigned to facet corner and center by grayscale variation
- System tracks movement of facet center and corners



White line – original location
Black line – deformed shape

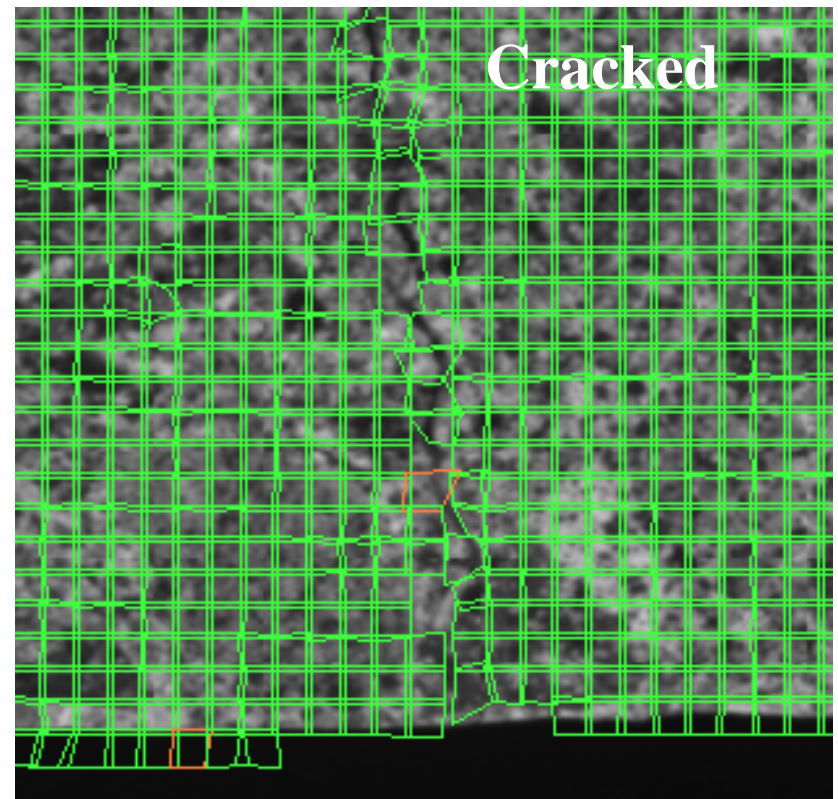
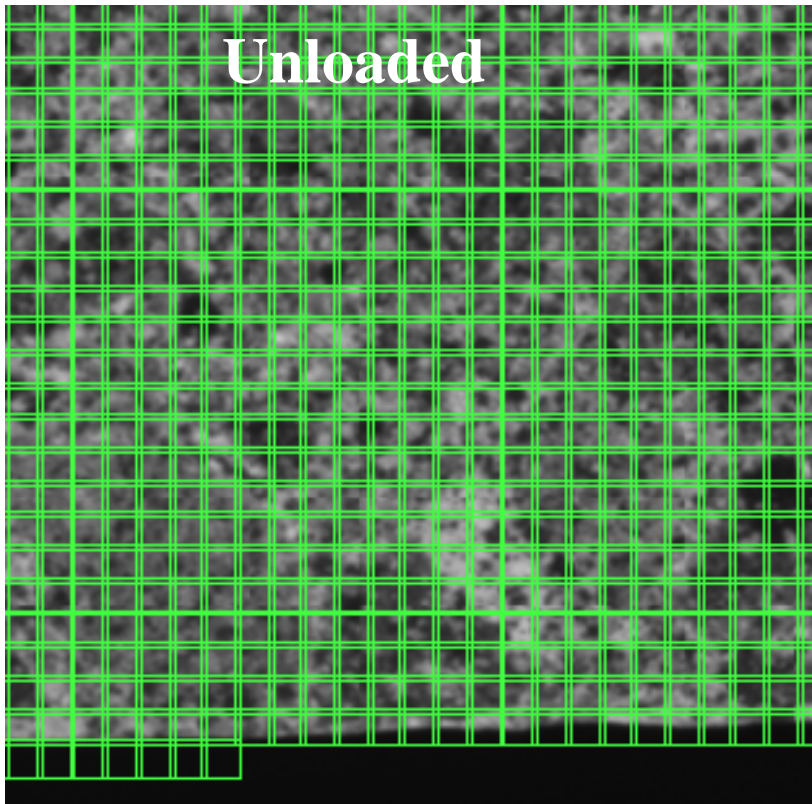
3-D Photogrammetry: Surface Preparation

- Grayscale contrast obtained by speckle pattern



3-D Photogrammetry: Deformation Measurement

- Sample deformation measured as mesh movements

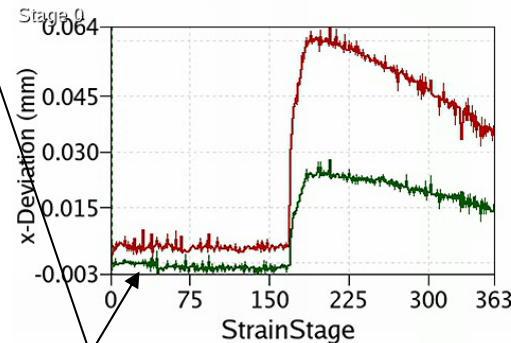


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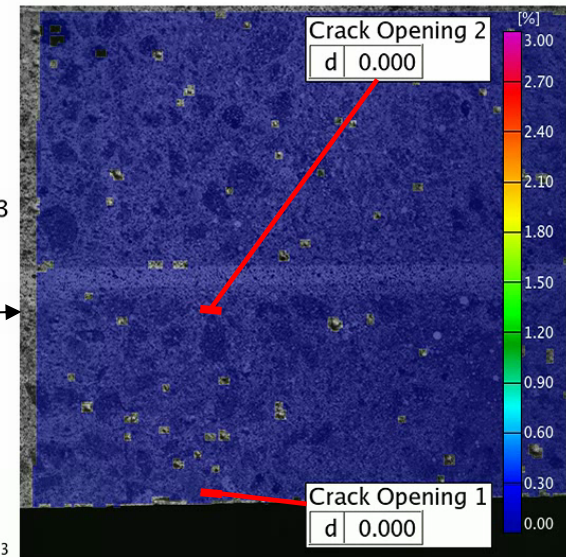
3-D Photogrammetry: Crack Geometry

- All beams loaded at constant rate, maximum – 3 min. unloaded – 3 min.
- Video of measured deformation projected on beam surface
- Crack opening measurements from tension face and near reinforcement



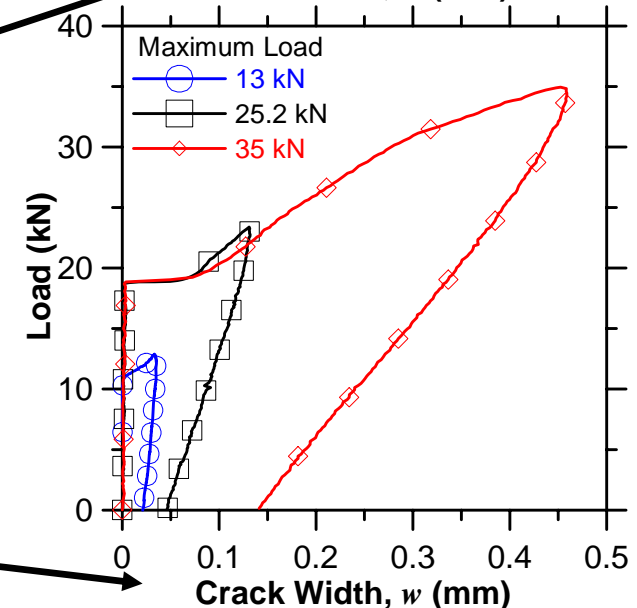
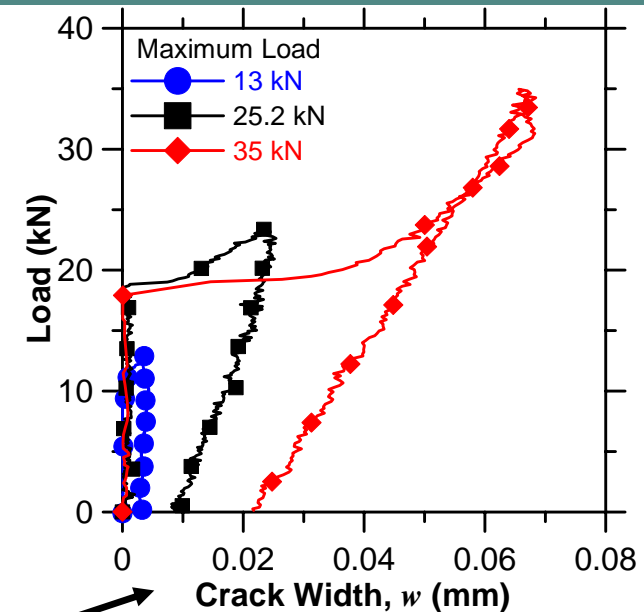
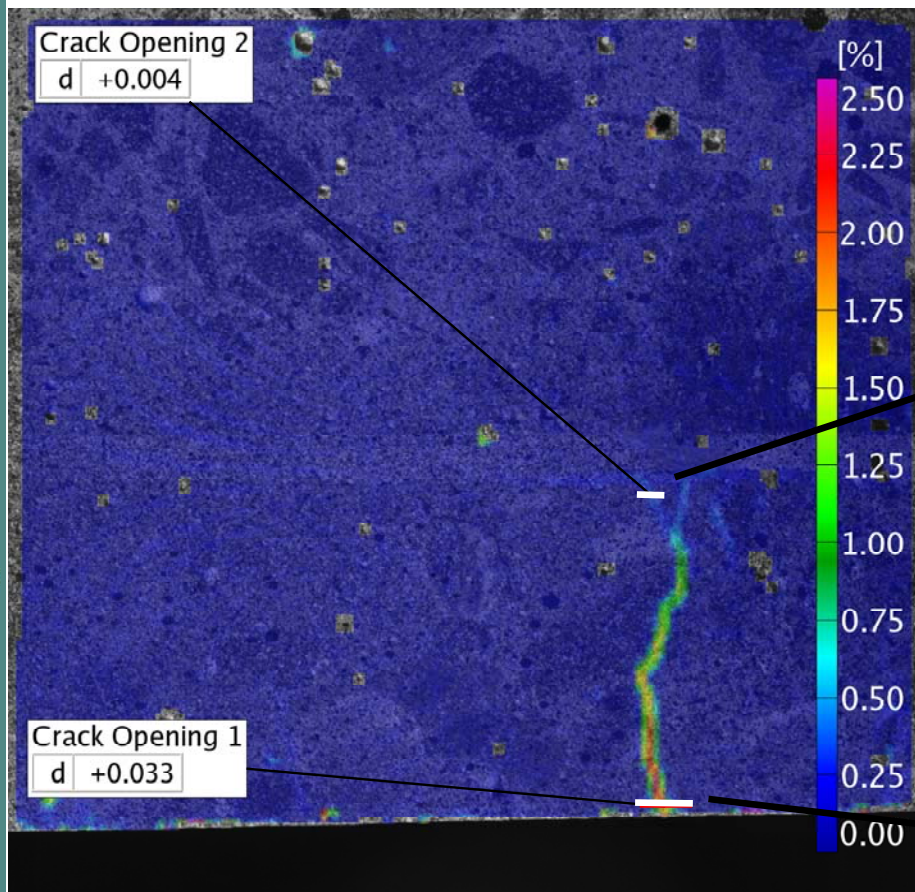
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— Crack Opening 1: X-Deviation
— Crack Opening 2: X-Deviation

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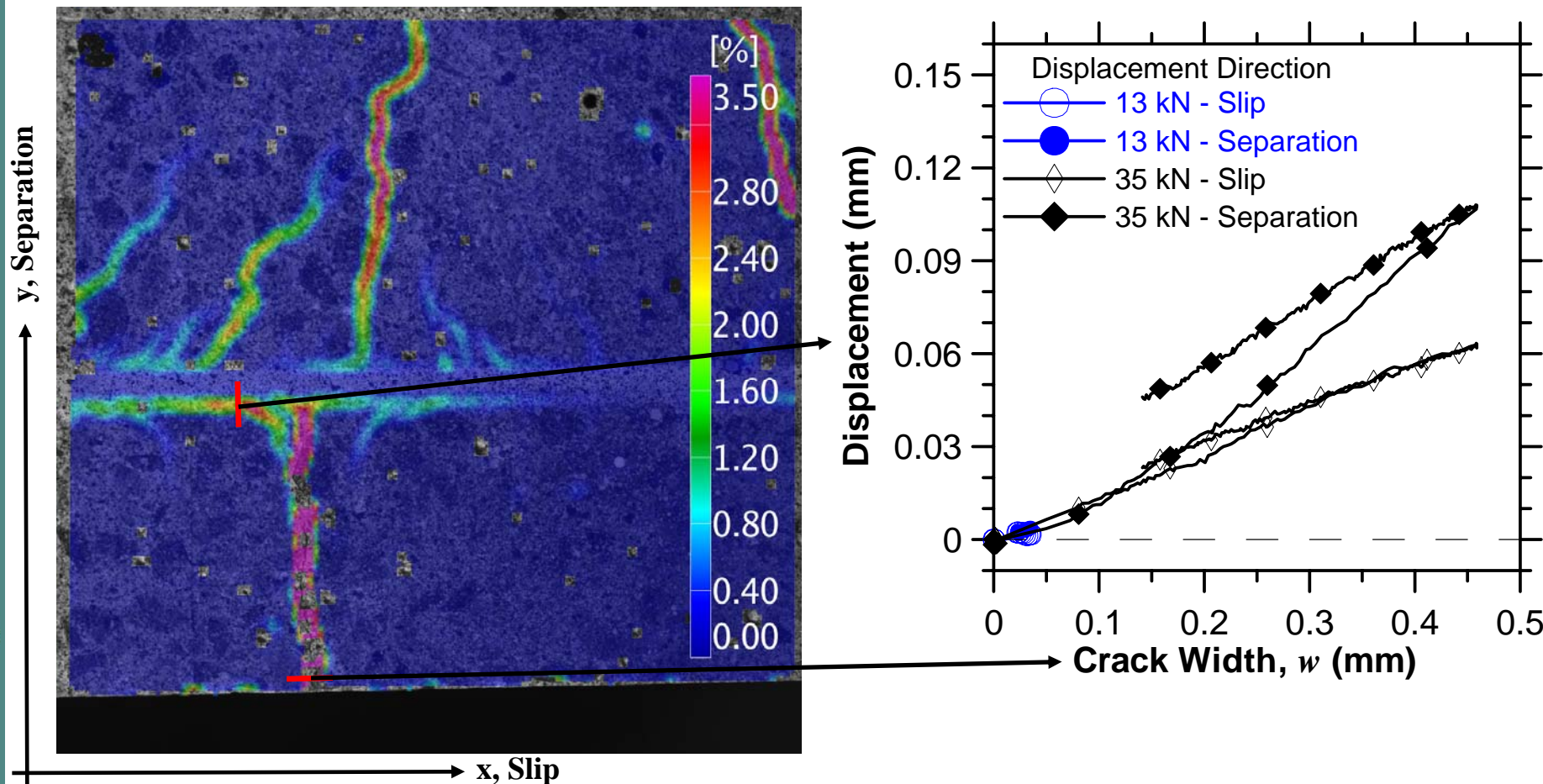
Crack Measurements: Crack Shape

- Load vs. crack width at various loadings from two locations
- V-Shaped crack



Crack Measurements: Slip and Separation

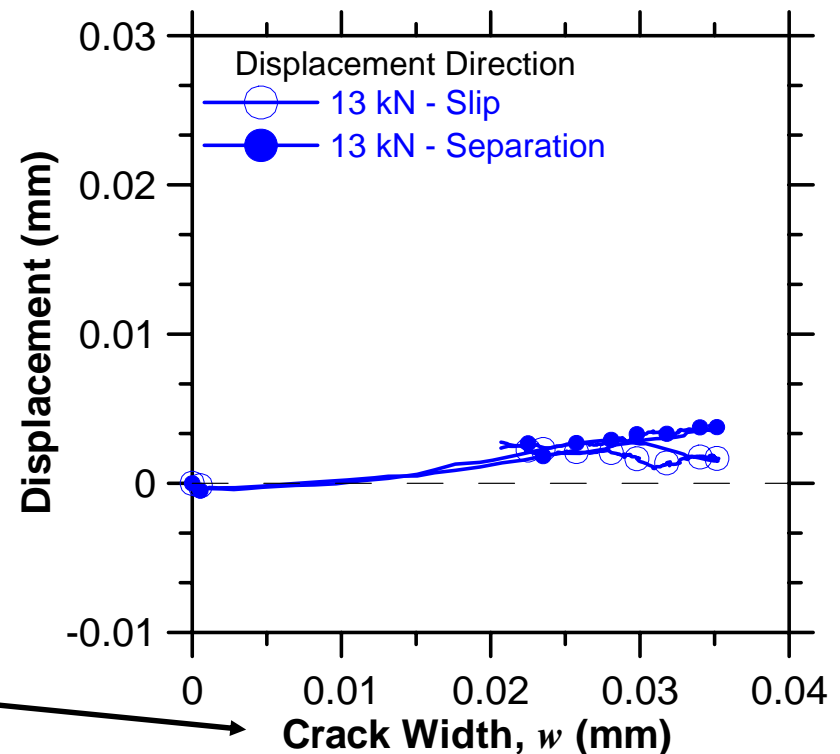
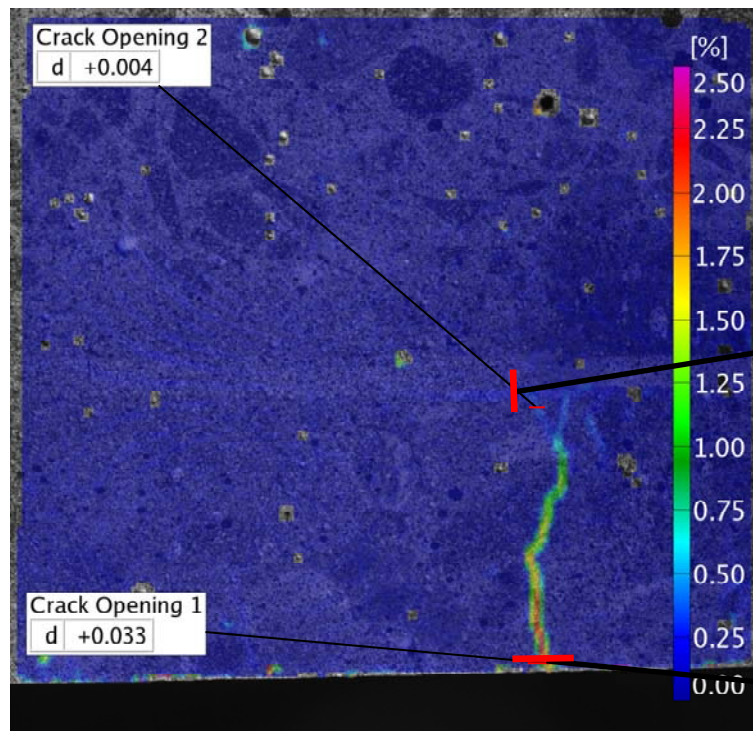
- Slip and separation vs. crack width near tensile face



- Elastic slip response, inelastic separation

Crack Measurements: Slip and Separation

- Initiation of slip and separation
 - At estimated cracking load
 - $\sim 4 \mu\text{m}$ measured slip and separation
 - Measured deformations close to resolution, results inconclusive



Conclusions

- 3-D Photogrammetry used to quantify cracking under flexural loading
- Slip behavior between reinforcement and concrete is elastic while separation behavior is inelastic
- Slip and separation between reinforcement and concrete initiates after opening of crack at tensile face

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